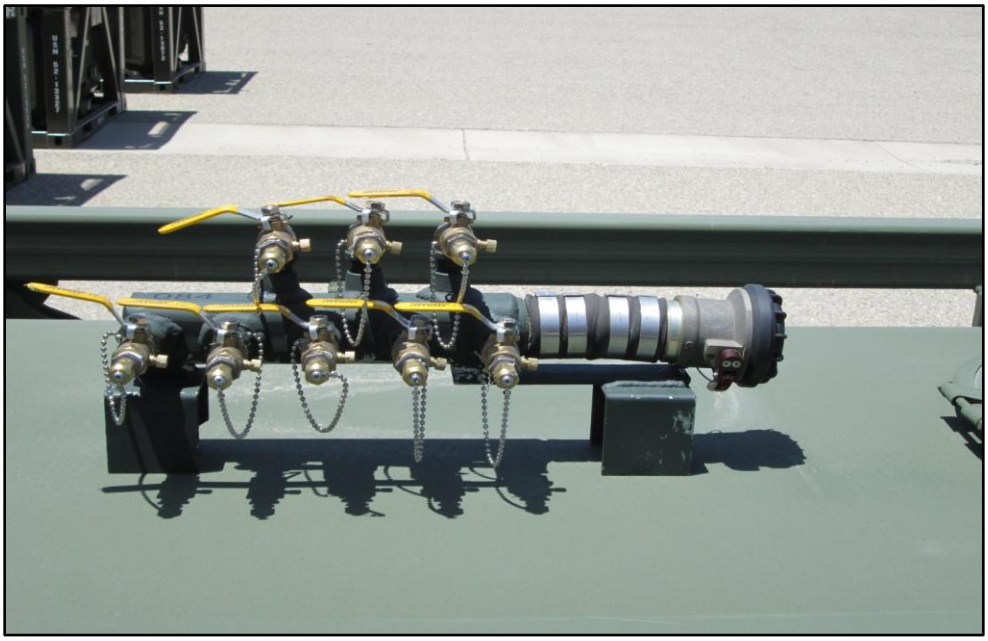
NAVFAC
Naval Facilities Engineering Command
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

TECHNICAL REPORT
TR-NAVFAC-EXWC-EX-1401
SEPTEMBER 2013

A BRIEF ENGINEERING ANALYSIS OF THE PROTOTYPE NEMSCOM MULTIPLE OUTLET MANIFOLD INTENDED FOR USE WITH THE SIXCON FUEL TANK ASSEMBLY (NSN 5430-01-240-4578)



James H. Estes

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EXECUTIVE SUMMARY

NAVFAC EXWC was requested to provide a brief engineering analysis and recommendations regarding the NEPO-generated Engineering Change Proposal (ECP) of 30MAY2012 titled "Addition of Manifold to SIXCON Fuel Tanks". The ECP relates to the creation of a multiple outlet fuel distribution manifold ("manifold") which would allow a single SIXCON Fuel Tank Assembly (NSN 5430-01-240-4578 - "SIXCON") to simultaneously provide fuel for up to 8 co-located ground units such as generators, etc. EXWC was requested to obtain documents from the Naval Expeditionary Medical Support Command (NEMSCOM) in order to fabricate a prototype unit, thence to create and execute a test plan for said unit. NEMSCOM subsequently provided EXWC two samples of the prototype unit obviating the need to produce a prototype in-house.

To first determine physical compatibility, an attempt was made to fit the manifold to several random deployment-ready SIXCONS located at NAVBASE Ventura County (NBVC) in Port Hueneme, CA. Three SIXCON outlet configurations were observed. The manifold was found to be incompatible with two of the three observed outlet configurations.

Following the physical compatibility determination, the prototype was examined from an engineering perspective keeping in mind the ultimate goal of creating a new capability that will be safe, reliable, and ready for deployment in the tactical arena.

Though sound in principle and practical in nature, several of the manifold components were found to be insufficiently robust for the tactical environment. Questions were raised that must be resolved before design finalization and meaningful testing can be performed. Questions centered on the appropriateness of features of some of the components, and required performance design parameters for the device. Recommendations for improvement and a partial listing of the additional information/steps needed before proceeding with final design and first article fabrication are provided.

In the absence of any actual or design performance criteria, no meaningful test plan could be created. It was recommended that in order to cost effectively create the new capability and ensure it will perform as needed in the tactical environment, required performance criteria should be established using detailed end user input, questions regarding the individual components should be addressed, and a step by step engineering approach leading to first article final design and fabrication be employed. Until the recommended activities are completed, further work with the prototype units provided is not warranted. It was then noted that EXWC has the capability to assist with the recommended efforts and would welcome the opportunity to do so.

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ACRONYMS AND ABBREVIATIONS

DoD	Department of Defense
ECP	Engineering Change Proposal
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NBVC	NAVBASE Ventura County
NEMSCOM	Naval Expeditionary Medical Support Command
NSN	National Stock Number

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1.0 BACKGROUND

The Navy Expeditionary Medical Support Command (NEMSCOM) tasked NAVFAC EXWC to provide technical support for the Engineering Change Proposal (ECP) titled "Addition of Manifold to SIXCON fuel tanks" dated 30MAY2012. The ECP relates to the creation of a small, multiple outlet manifold ("SIXCON Fuel Manifold") to facilitate simultaneous fuel distribution to multiple stationary ground units (i.e. generators, etc.). On 29MAY2013, the undersigned was asked participate in a meeting with the Project Manager (Ramon Balajadia) and others for the purposes of providing guidance from an engineering perspective, and points of contact that might prove useful in the effort. Subsequent to the meeting, NEMSCOM provided two virtually identical prototype units to EXWC for examination. As the intended use for the SIXCON Fuel Manifold is with the SIXCON Fuel Tank Assembly (NSN 5430-01-240-4578; henceforth "SIXCON"), the approach was to first determine physical compatibility of the manifold with several random, deployment-ready SIXCON fuel tank assemblies located at NAVBASE Ventura County (NBVC) in Port Hueneme, California. After determining SIXCON compatibility of the manifold as configured, the manifold was analyzed from an engineering perspective. The results of the compatibility study and engineering analysis are documented herein. The following observations, comments and recommendations are offered in the hope that EXWC can facilitate development of the NEMSCOM manifold into a cost effective, safe, and reliable end item for our warfighters in the tactical environment.

2.0 FINDINGS

2.1 SIXCON Compatibility

There were three different outlet configurations encountered on the SIXCON fuel tanks even though they all carried the same NSN number, NSN-5430-01-240-4578. The manifold, which is designed to sit on the bottom frame of the SIXCON module while straddling one of the forklift pockets, was incompatible with two of the three configurations. (See Figures 2-1 through 2-7.) Even if the end users were provided hardware and tools to modify the SIXCON outlet configurations #2 and #3 to fit the manifold, the outlets are below the liquid level of the tank and not subject to field alteration with fuel in the tank.

Figure 2-1. Outlet Configuration #1

Figure 2-2. Outlet Configuration #1 with Manifold Installed

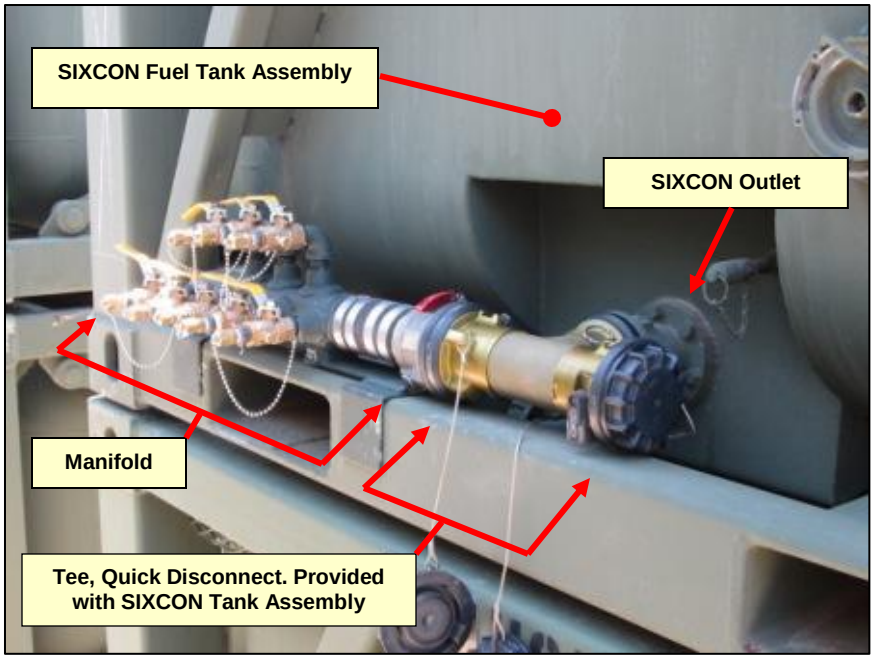

Figure 2-3. Outlet Configuration #1 with Manifold Installed

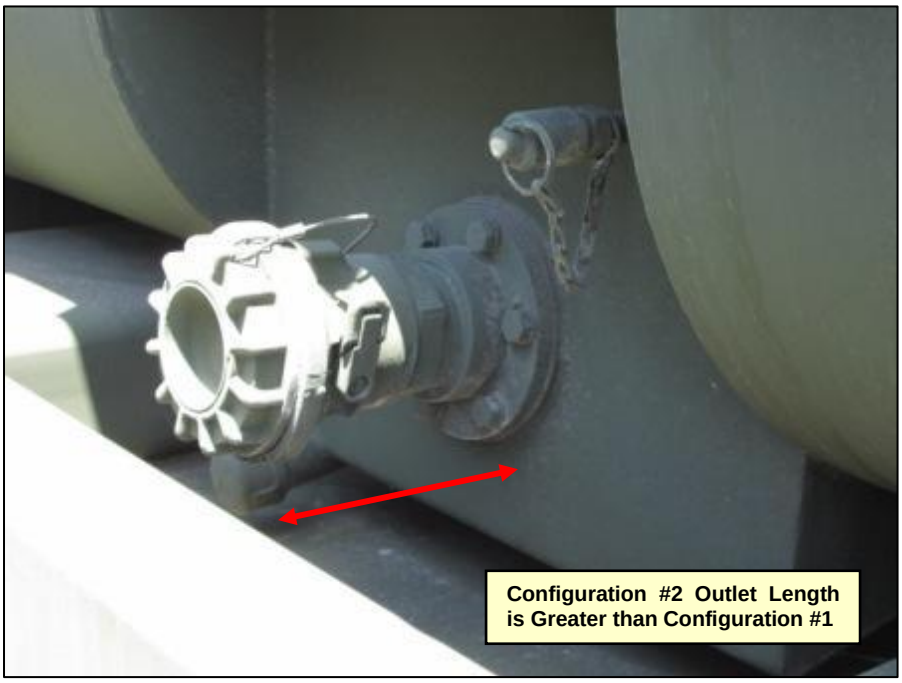

Figure 2-4. Outlet Configuration #2.
Manifold Can Not Be Installed on This Outlet Configuration

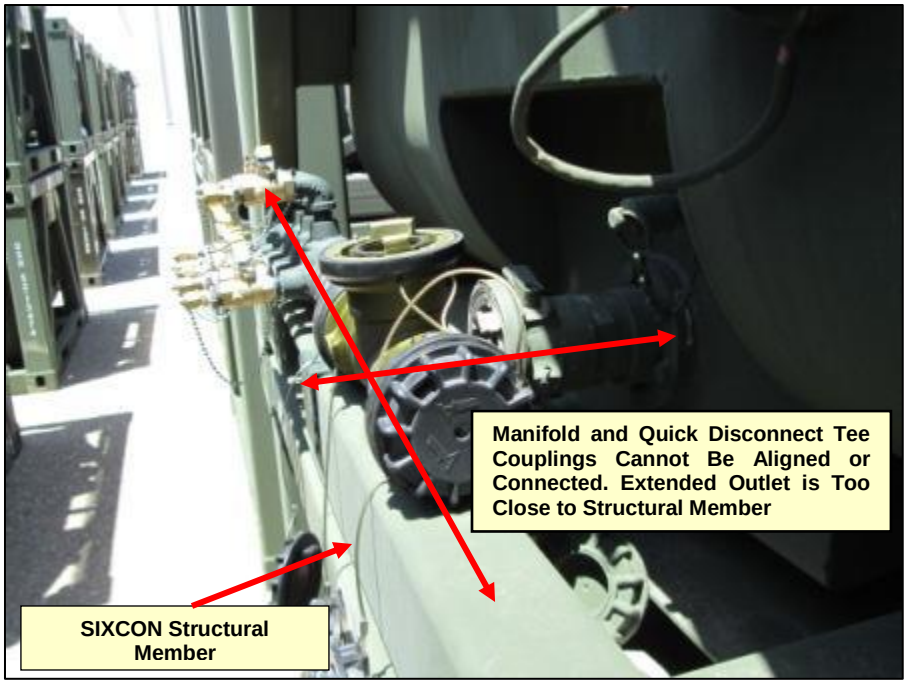

Figure 2-5. Outlet Configuration #2.
Manifold Can Not Be Installed on This Outlet Configuration

Figure 2-6. Outlet Configuration #3

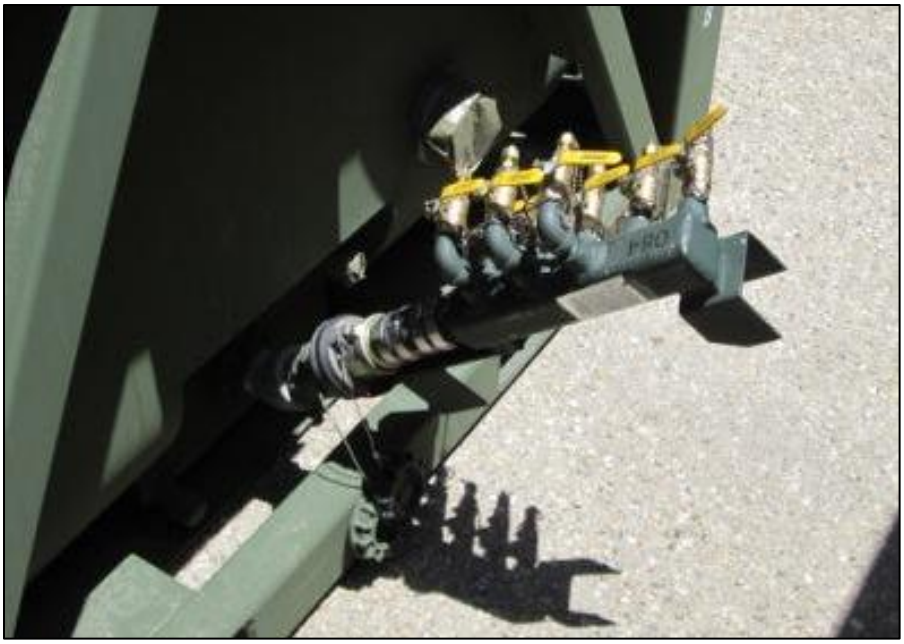

Figure 2-7. Outlet Configuration #3.
Manifold Not Properly Oriented or Supported. Manifold Cannot Be Safely Used With This Outlet Configuration

All SIXCONs observed at NBVC had "USMC" stamped on their data tags. (The USMC has a single fuel forward policy and uses JP-8 only.) Some units were stenciled "Diesel Fuel Only", some stenciled "FUEL ONLY" and others with no markings as to the contents (see figures 2-8 and 2-9). None of the SIXCONS observed were stenciled "JP-8 Only". It is reasonable to expect that due to the exigencies of warfare and prevailing conditions in service, the manifolds and all components could see service with any of the common fuels used in theater by the Navy/Marine Corps.

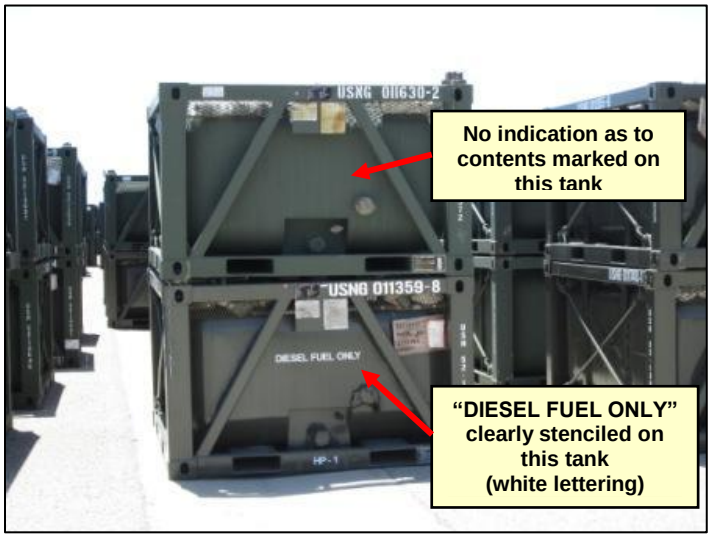

Figure 2-8. Inconsistent Contents Markings

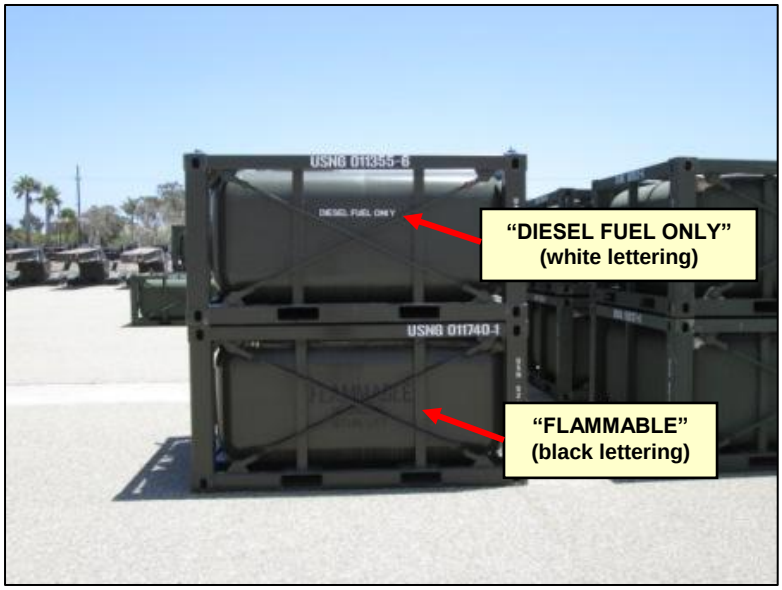

Figure 2-9. Inconsistent Contents Markings

2.2 Overall Appearance and Configuration

The manifold is a classic example of field personnel expediently addressing their needs through the creation of viable solutions using readily available resources. As is often the case, end users should be commended for their resourcefulness, creativity and willingness to move our war fighting technologies forward. From an engineering perspective, several features and components of the prototype unit warrant comment prior to freezing the design and producing a pre-production prototype.

As configured, the three upper outlet valves are positioned well above the lowermost portion of the existing SIXCON tank outlet (see figure 2-3). This configuration reduces the amount of usable fuel that can be gravity-fed to the receiving ground units as compared to that available through the five lower outlet valves. Ideally, the manifold should be configured to provide access at any of the multiple outlet valves to all of the fuel available at the standard SIXCON outlet (i.e. all usable fuel in the SIXCON) rather than limit fuel accessibility at some positions.

2.3 Outlet Valves

In the absence of any literature, it is unknown for which fluids and pressures the valves are rated. In the absence of engineering data or design criterion, it is unknown as to what pressures the manifold is designed to operate or what safety factors have been observed during design. Outlet valve suitability for use cannot be determined (see figure 2-10).

2.3.1 Outlet Valve Handles

The handles on the outlet valves are not sufficiently robust for service in the tactical environment. The handles on the unused sample units provided were received bent and misshaped just by the rigors of non-tactical, commercial transport alone. Transport and use in the tactical environment will be significantly more challenging than standard CONUS commercial shipping. Repeated bending and straightening will lead to handle failures, which would in turn render the individual valve unusable.

2.3.2 Outlet Valve Ports

It is understood that the NEMSCOM prototype manifold was fabricated with flared fittings on the outlet valves to expediently interface with a readily available fuel hose, NSN 4720-00-021-3320. This configuration does not seal either the valve or hose when disconnected. To reduce the possibility of a fuel spill if frequent connections/disconnections are anticipated (no information on the frequency of connections/disconnections was provided) the flared outlet ports on the outlet valves as well as the connecting ends of the hoses, should be fitted with suitable dry-break couplings..

2.3.3 Outlet Valve Protective Cap Retention

The small retaining chains on the outlet valve protective caps and their attachment means (plastic wire-ties) are not sufficiently robust for the tactical environment and will likely fail in service. Loss of the outlet valve protective caps will ultimately lead to damage to the threads and flared ends of the outlet valve fittings, rendering them unusable. All outlet valve protective caps should have retaining cables or tethers of similar size and strength to those utilized on the large dry-break manifold inlet valve dust cap, the SIXCON outlet valve dust cap, and the SIXCON quick disconnect tee dust caps to prevent loss.

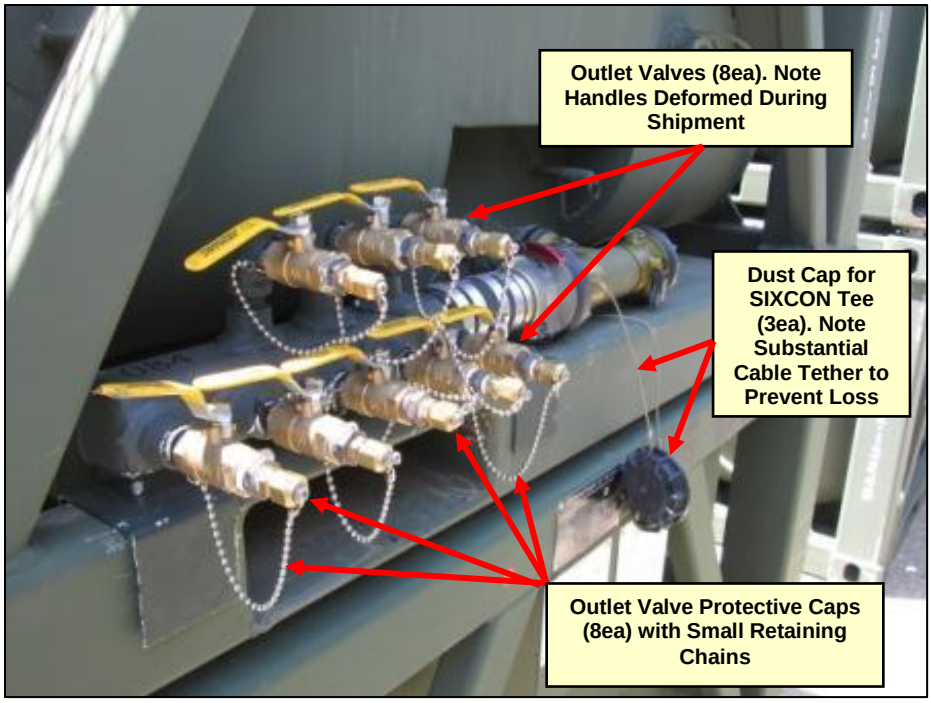

Figure 2-10. Outlet Valves

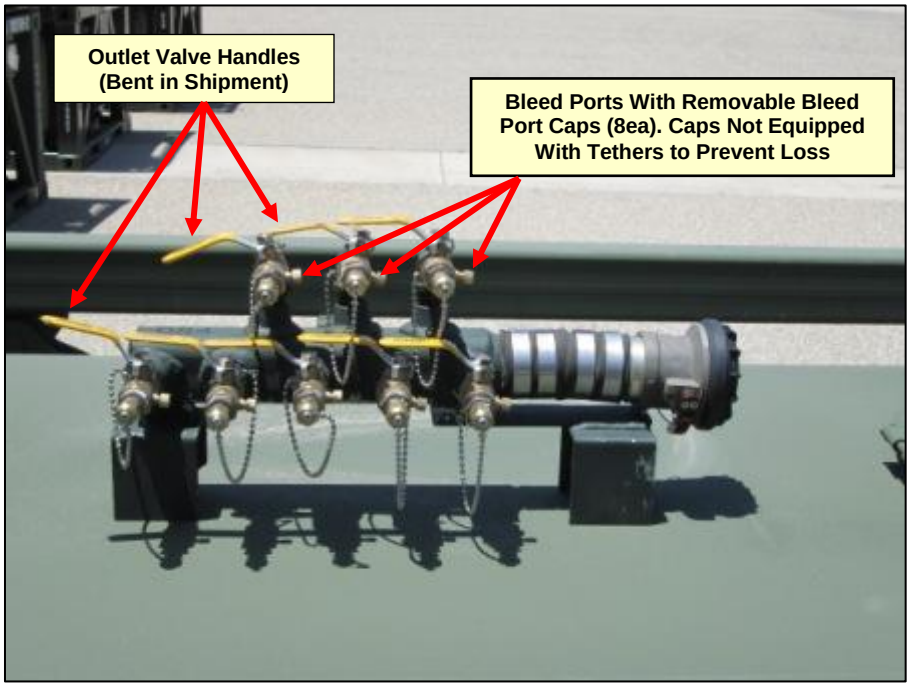

Figure 2-11. Bleed Ports with Removable Bleed Port Caps

2.3.4 Outlet Valve Bleed Ports and Caps

The outlet valves have small caps on the side, which cover what are apparently air bleed, sensor access (pressure, temperature, etc.) or perhaps sampling ports ("bleed ports") (see figure 2-11). The author is unaware of a useful purpose for the bleed ports in this application and concerned about them providing a potential leakage path. A leakage path could either introduce air into the outlet lines (which would typically be connected to the suction side of a ground unit fuel pump) or result in a fuel spill with the associated hazards. If there is indeed no requirement for the bleed ports and accompanying caps, it is recommended they be eliminated.

The small bleed port caps have gaskets inside made of unknown material. If bleed ports and caps must be included on the unit for function as determined by the end user, it should be insured that the bleed port cap seals (as well as the outlet valves themselves) are made of materials compatible with any fuel to which they could possibly be exposed in the field. This should include as a minimum DL-2, JP-5 and JP-8.

2.3.5 Outlet Valve Bleed Port Cap Retention

The bleed port caps do not have any form of retaining means to prevent loss. If the bleed port cap from any valve is lost, that valve then becomes unusable. All bleed port caps (again, if bleed ports and caps are necessary for function as determined by the end user) should have retaining cables or tethers of similar size, strength and attachment means to those on the large dry-break manifold inlet valve dust cap, the SIXCON outlet valve dust cap, and SIXCON quick disconnect tee dust caps to prevent loss.

2.4 Manifold Inlet Coupling and Connection

The large dry-break manifold inlet coupling is connected to the body of the manifold with a short section of minimally flexible rubber hose and four single use clamps. The coupling, rubber hose and multiple clamps should be replaced with a single threaded dry break coupling of the correct size, threaded into an appropriate-size socket weld x threaded coupling welded to the main body of the manifold. A rigid, threaded connection would be more durable than the clamped hose connection and less susceptible to leaks or potential damage. As a side note, there is no need for any flexibility at the manifold inlet coupling attachment, as standard tolerances for these types of devices should allow for any minor dimensional variations between SIXCON units. Compatible threaded dry-break couplings are readily available in the commercial marketplace.

2.5 Surge Protection

No evidence has been provided indicating line pressure surge considerations were made during construction of the prototype units. Line surge may well have been considered, but in the absence of accompanying literature or data indicating to what levels of surge protection the unit has been designed to withstand, the following comments are offered. Upon initial EXWC inspection, the basic structure (not including the outlet valves and protective cap retention chains) appears to be relatively robust. However, "appears relatively robust" is not sufficient criterion from which to evaluate the design of or to appropriately test military hardware. Along similar lines, no indication of maximum operating pressure, a critical value, has been provided.

To proceed from hand-built field expedient prototype to a manufacturable appliance suitable for use in the tactical environment, an analysis of maximum operating and potential surge pressures should be performed. Though beyond the scope of this document, for a practical cost effective approach to determine an appropriate design maximum operating pressure, one could investigate and likely utilize the lesser of the maximum rated operating pressures of the standard SIXCON pump unit, the SIXCON hose assemblies, or the quick disconnect TEE provided with the SIXCONS. Since a production manifold connected to a SIXCON would likely experience not only the same operating pressures but also the same potential surge pressures, safe surge pressure design criterion for the manifold (and all of the manifold components) could safely and cost effectively be taken from the above components as well.

Although it is anticipated that the greatest surge threats will originate with the existing SIXCON system and related attachments, it should be noted that the outlet valves would also be subject to any downstream-generated surge pressures. To determine likely downstream surge pressures (again, beyond the scope of this document) breadboard testing will be necessary. The manifold should be operated with at least two outlet valves fully open and fuel flowing at the maximum anticipated rate, thence fuel flow abruptly halted in both paths simultaneously by test valves at the distal end of the individual component supply hoses (i.e. the hoses supplying the individual ground units). This would yield a practical design value for downstream surge pressure likely to be encountered in the field. In the absence of actual test data, it is suspected that any surge pressured downstream would likely be less than those the existing SIXCON attachments are designed to withstand, but in the interest of safety, actual testing is recommended.

2.6 Durability

It is doubtful that the manifold as currently constructed would withstand the standard drop and vibration tests typically required for military hardware (dropped from a height of three feet onto a hard surface from all six sides and eight corners). After determining how the manifold will be transported (i.e. via ground transport as restrained vs. loose cargo) it is recommended that adequate means be incorporated to insure survivability during transport and use of a redesigned unit (refer to MIL-STD 810G).

3.0 COMMENTS

3.1 Further Analysis and Redesign

As alluded to earlier, the NEMSCOM SIXCON Multiple Outlet Fuel Manifold device is representative of the high levels of creativity and resourcefulness so often demonstrated by our troops in the field. To successfully transition the manifold from expedient prototype to field-ready, tactical environment appliance, a more in-depth engineering analysis and redesign are recommended. A thorough in-depth analysis and redesign would increase durability, serviceability, safety and likely reduce overall cost to the taxpayer.

Listed below are a few representative (but certainly not all) questions that must be answered before the design can be finalized, a final prototype built or a meaningful test plan created:

1. What are the needed flow rates and pressures?

2. What drop and vibration specifications/standards must it meet?
3. How will it be transported?
4. What skills will the end users require for operation?
5. With which SIXCON outlet configurations must it interface?
6. How will it be supported/repaired in the field?
7. Can it be made with all standard/readily available military hardware?
8. Why eight outlet valves instead of four … or ten?
9. Are bleed ports on the outlet valves needed for the intended use scenario?
10. How are spills prevented when disconnecting outlet hoses?
11. Which outlet hose configurations and hardware will the end users have available to them?
12. How will grounding/static discharge be handled?

3.2 Test and Evaluation

Although initial tasking for EXWC included the development of a test plan for the prototype units, at this time, initiation of test plan development would not be the most cost effective approach. Adequate performance criteria against which the prototypes can be evaluated have not yet been made available. It is also known that a partial redesign is warranted to make the unit more suitable for the tactical environment and safer for the end user. Test plan development can most effectively proceed after full performance criteria have been established and the design finalized.

3.3 Suggested Course of Action

The ability to simultaneously supply multiple stationary ground units from a single fuel source would be a useful capability in a variety of venues. Not only could a device such as NEMSCOM has proposed via the SIXCON Fuel Manifold benefit units using SIXCON Fuel Tank Assemblies as the central source, but such a device could benefit a wide variety of units using pillow tanks, bladders, trailer-mounted portable tanks and other central fuel storage means as well. It is suggested that work on the NEMSCOM prototype and its variants be discontinued. Instead, an increased level of engineering involvement regarding this new capability should be undertaken, the goals of which would be to a) clearly and accurately determine design and performance requirements as they pertain use with SIXCONs, pillow tanks, bladders and a variety potential central reservoirs and venues; b) design and fabricate first article samples in accordance with the determined requirements; and c) develop and execute a test plan to determine compliance with said requirements.

EXWC is fully capable of working with a wide variety of potential end users, applicable MIL-STDs, existing hardware databases, etc. to establish appropriate design criteria. EXWC is available to perform the overall design tasks, create manufacturing documentation and support packages, and oversee production and testing of a redesigned multiple outlet distribution device such that benefits are available to the greatest number of potential users and costs to acquire the new capability are minimized.

4.0 RECOMMENDATIONS NOT SPECIFICALLY RELATED TO THIS TASK

4.1 Noted Items

During the course of this brief engineering analysis, items were noted for which further study and resolution are recommended:

- Why were three different outlet configurations on the "standard" SIXCON Fuel Tank Modules observed during the compatibility study, and which of the three is/are actually deployed to the field?
- Why was there inconsistent content identification stenciling on the SIXCONS observed, and which of the three is/are correct?
- During the SIXCON Physical Compatibility portion of this analysis, (Section 2.1) attempts were made to couple the standard Quick Disconnect tee (supplied with the SIXCONs) to five random SIXCON units having Outlet Configuration #2 prior to checking manifold fit (See Figures 2-4 and 2-5). On two of the five observed configuration #2 units, the tee could not be fully coupled to the SIXCON tank outlet due to interference with the lower structural member of the SIXCON. The tee could be successfully coupled to the tank outlets on the remaining three units, but as earlier stated, the manifold could not be coupled to the tee. Inconsistencies in tee fitment should be investigated and corrected.

These items will affect the deployment and ultimate use of the manifold but are beyond the scope of this specific report.

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